1. Specific Differential Phase (KDP)

Instructor Notes: Welcome to the dual polarization radar course. I am Clark Payne with the Warning Decision Training Branch. This lesson is part of the dual-pol products section and will cover the product specific differential phase. It should take you approximately 20 minutes to complete.

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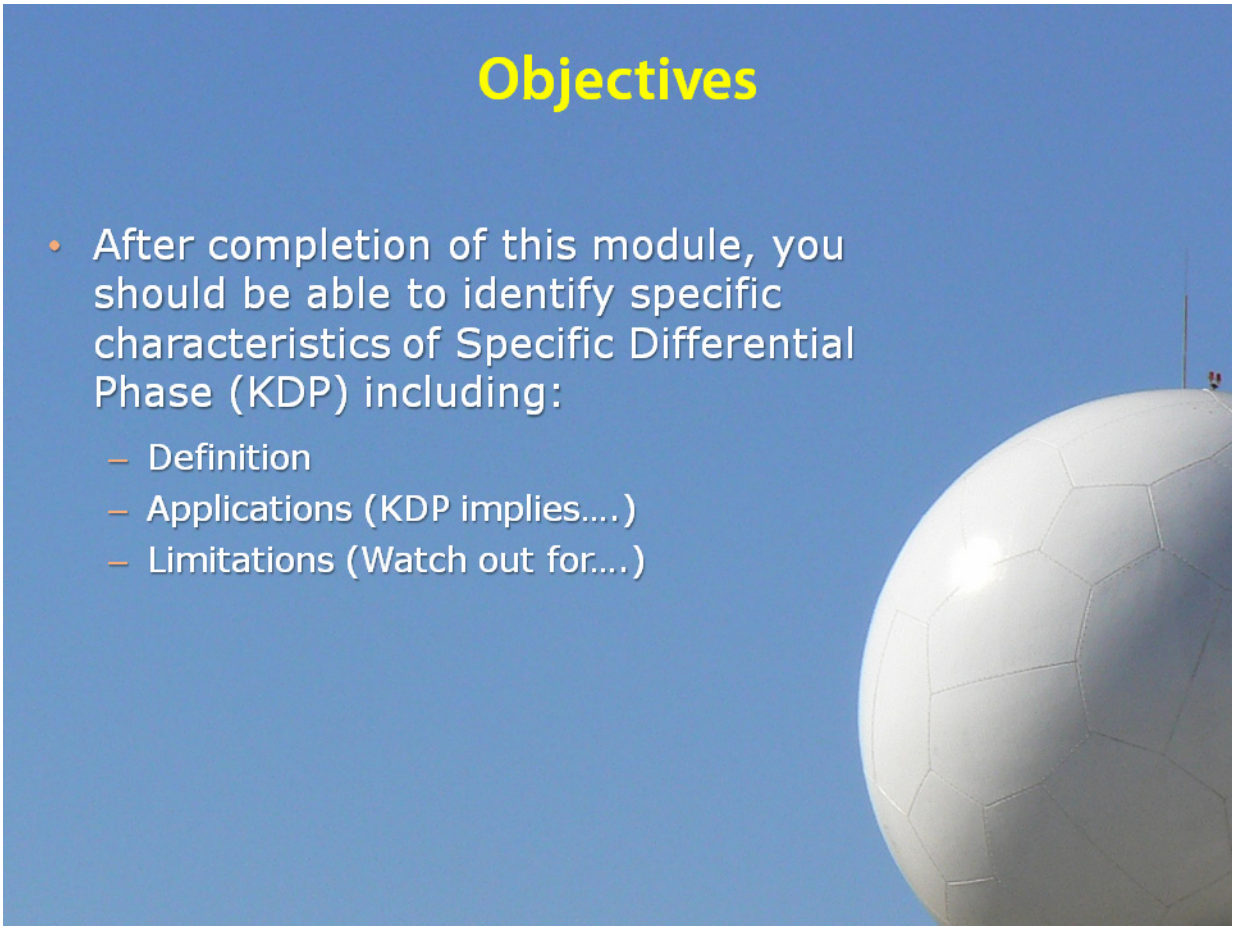

2. Objectives

Instructor Notes: Here are the objectives for this lesson. Please take a few moments to look through these. Advance the slide when you are ready.

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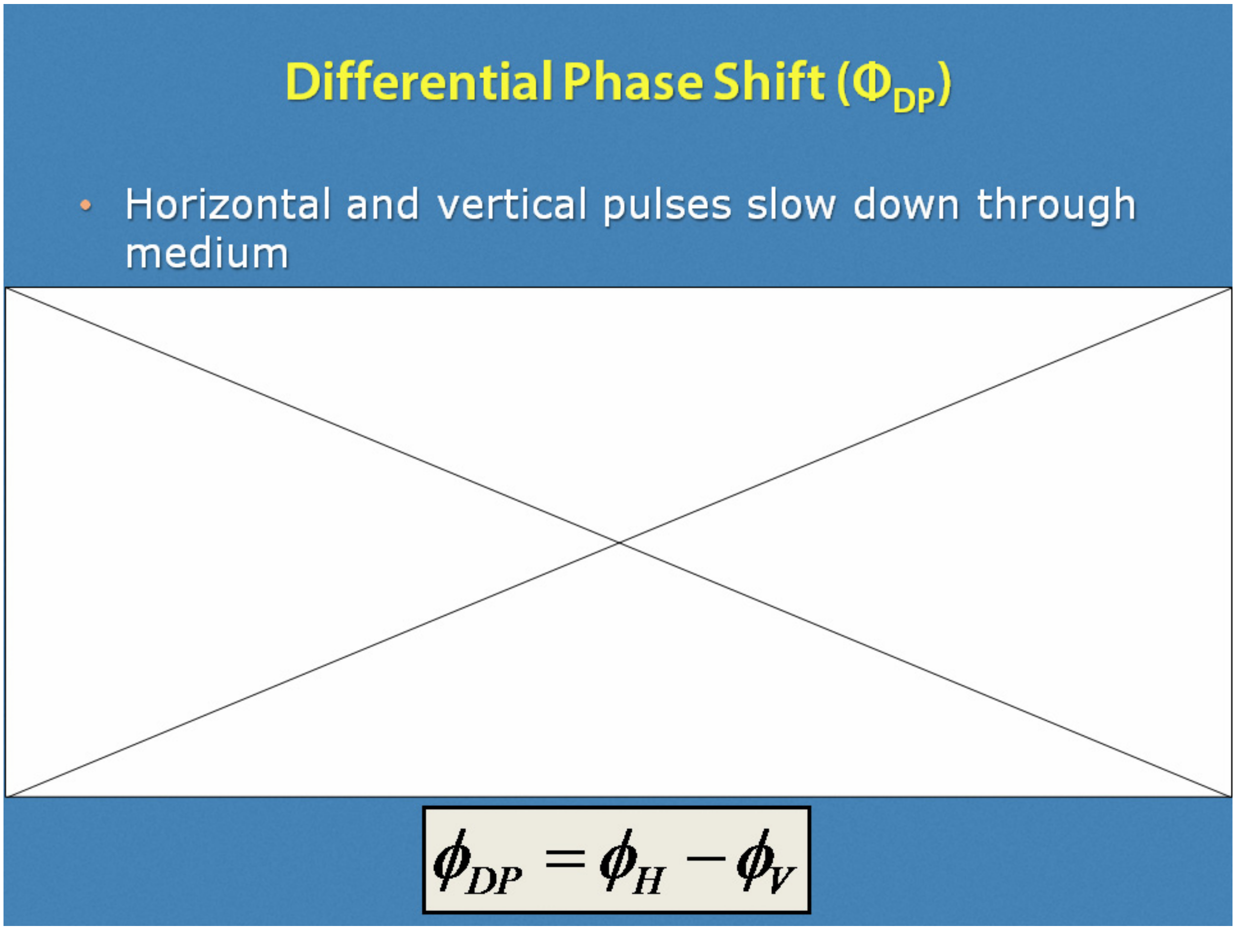

3. Differential Phase Shift (ΦDP)

Instructor Notes: As discussed in one of the dual-pol RDA lessons, dual-pol radars measure differential phase shift, while the RPG generates specific differential phase shift, which you will be interpreting in AWIPS. We need to define what differential phase is first, then discuss what we mean by "specific" differential phase. As the horizontal and vertical pulses propagate through a medium (i.e. rain, hail, etc.) the two pulses attenuate (or slow down) causing each of their phases to change (or shift) as shown here in the animation (yellow = horizontal pulse, red = vertical pulse). Most targets do not have equal phase shifting in the horizontal and vertical due to target shape and concentration. This difference between the horizontal and vertical phase shifts is referred to as the differential phase shift. Mercifully, the equation is just a simple subtraction, such that positive differential phase shift occurs when horizontal phase shift is greater than the vertical.

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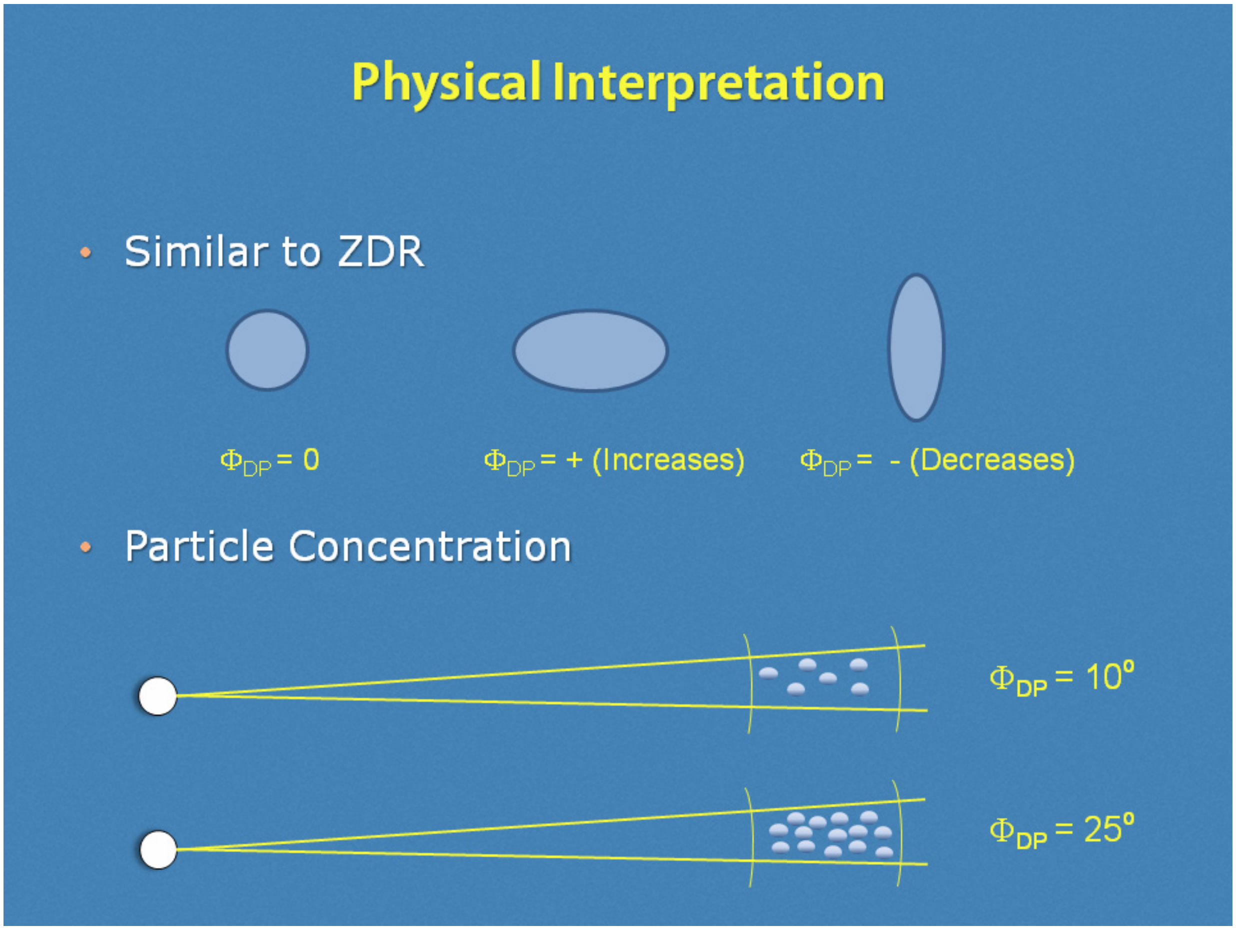
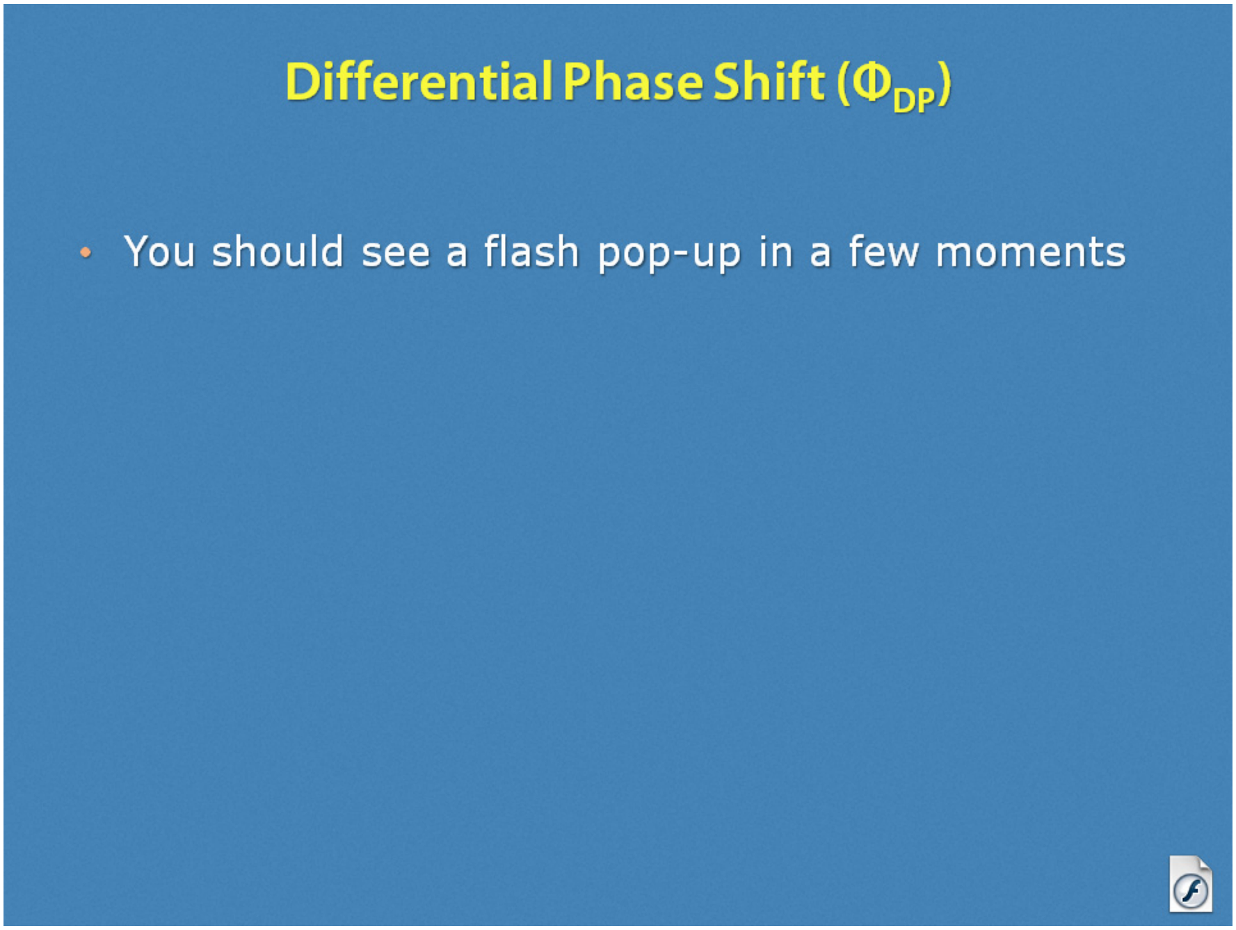


4. Physical Interpretation

Instructor Notes: Much like differential reflectivity, the shape of the target affects the differential phase shift. Horizontally oriented targets will produce an increasing, positive differential phase shift with range. Vertically oriented targets will produce a decreasing, negative differential phase shift with range. And, spherical targets will produce near zero differential phase shift with range. Additionally, unlike ZDR, differential phase shift is dependent on particle concentration. The more particles there are in a pulse volume, the more differential phase shifting will occur. For example, the more horizontally oriented targets there are within a pulse volume, the higher the positive differential phase shifting.

Student Notes:



5. Differential Phase Shift (ΦDP)

Instructor Notes: In a few moments, a flash video will pop-up showing you an animation illustrating differential phase shift. Play around with this for a bit, being sure to play the animation with and without hail. You'll notice that because hail is effectively spherical, adding it to the pulse volume does not increase differential phase shift at all. Additionally, increasing the amount of rain increases differential phase shift accordingly.

Student Notes:

Specific Differential Phase (KDP)

Definition	Possible Range of Values	Units	Abbreviated Name
The range derivative of the differential phase shift between the horizontal and vertical pulse phases	-2 to 7	Degrees per Kilometer (deg/km)	KDP

$$KDP = \frac{\phi_{DP}(r_2) - \phi_{DP}(r_1)}{2(r_2 - r_1)}$$

6. Specific Differential Phase (KDP)

Instructor Notes: How do we get from differential phase to specific differential phase, the product you see in AWIPS? The specific differential phase is defined as the range derivative of the differential phase shift between the horizontal and vertical pulse phases. Possible values range from -2 to 7 in units of degrees per kilometer. In AWIPS, GR Analyst and the literature you will see specific differential phase abbreviated as KDP. The factor of 2 in the denominator accounts for the trip out and back by the pulses. The next several slides will examine in detail the physical characteristics of KDP.

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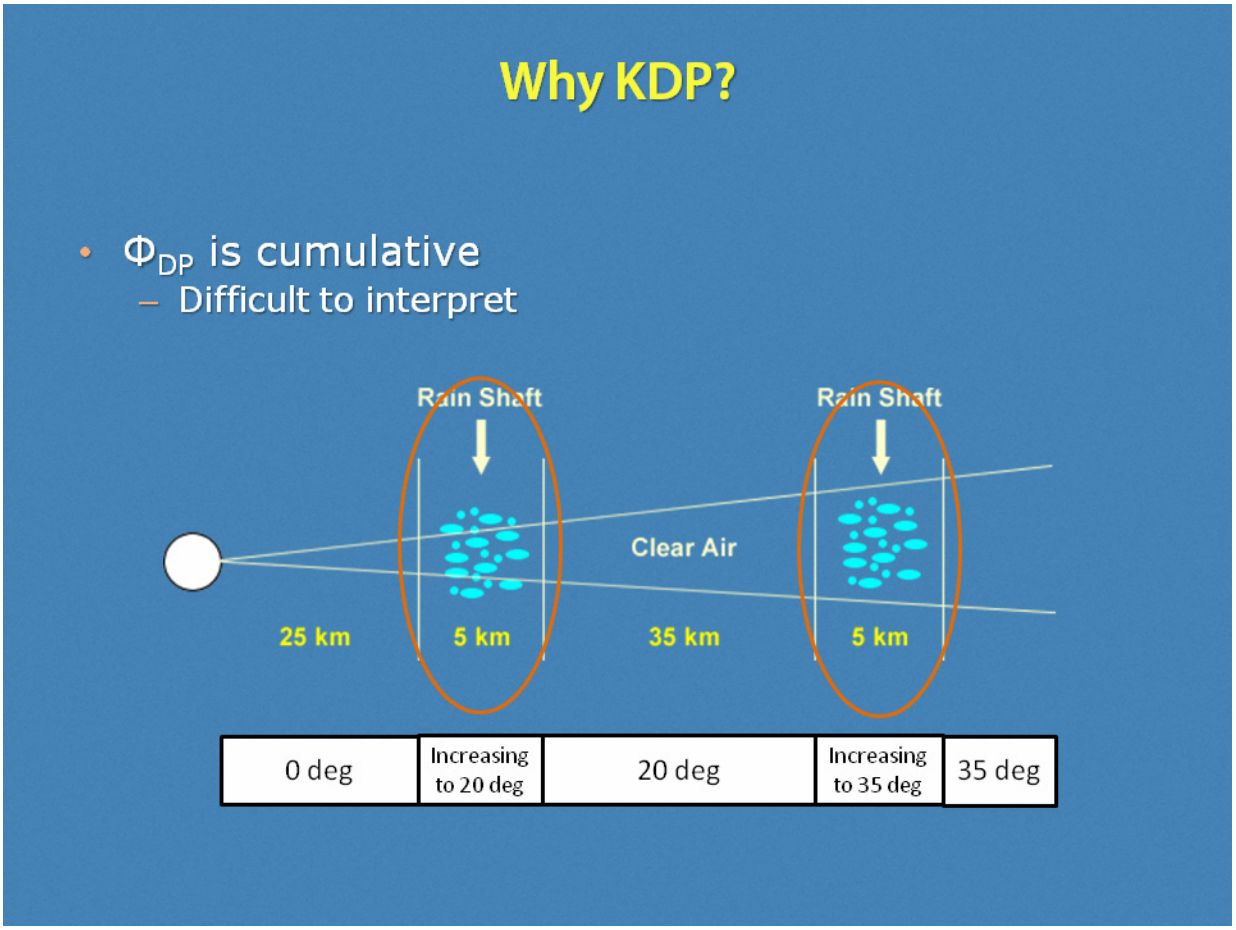
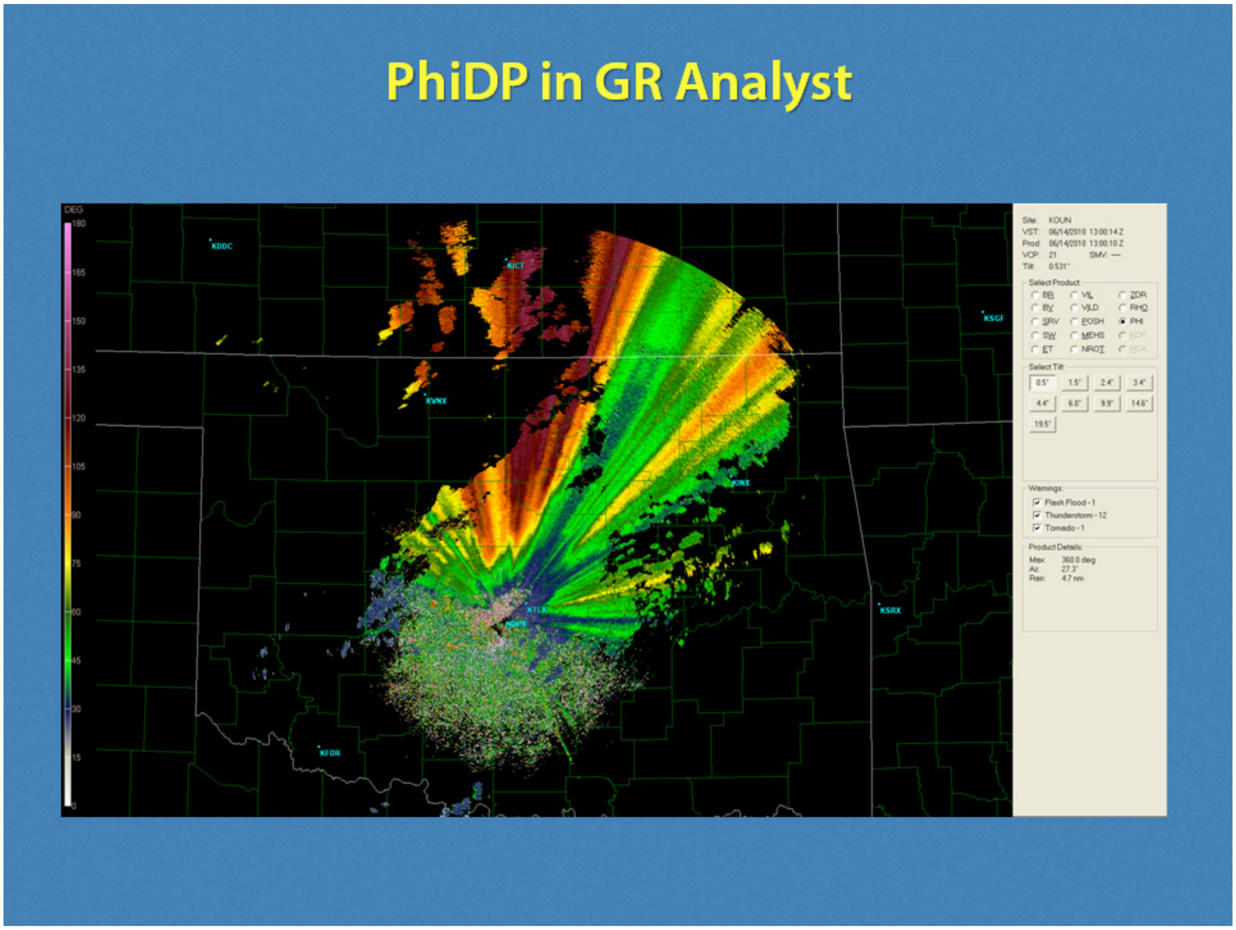


7. Why KDP?

Instructor Notes: So, what is the reason for KDP? Let's look at the example here of PhiDP for two rain shafts at 30 and 70 km from the radar. As the horizontal and vertical pulses propagate toward the first rain shaft, they experience zero differential phase shifting, so PhiDP is zero. As the pulses go through the first rain shaft, the horizontal pulse slows down faster than the vertical pulse resulting in a positive differential phase shift. We'll say it is 20 degrees. After exiting the rain shaft, the pulses enter clear air and experience zero additional differential phase shifting. However those bins in the clear air will show a differential phase shift of 20 degrees because the differential phase shift cannot reset itself along a radial. In the second rain shaft, the differential phase shift will increase again, and let's say it increases by 15 degrees. In those bins and any bin further down range, the differential phase shift will be 35 degrees. As you can see, the differential phase shift is cumulative and the absolute value tells you nothing about what is going on in that particular bin, but rather all that has happened along the radial up to that point.

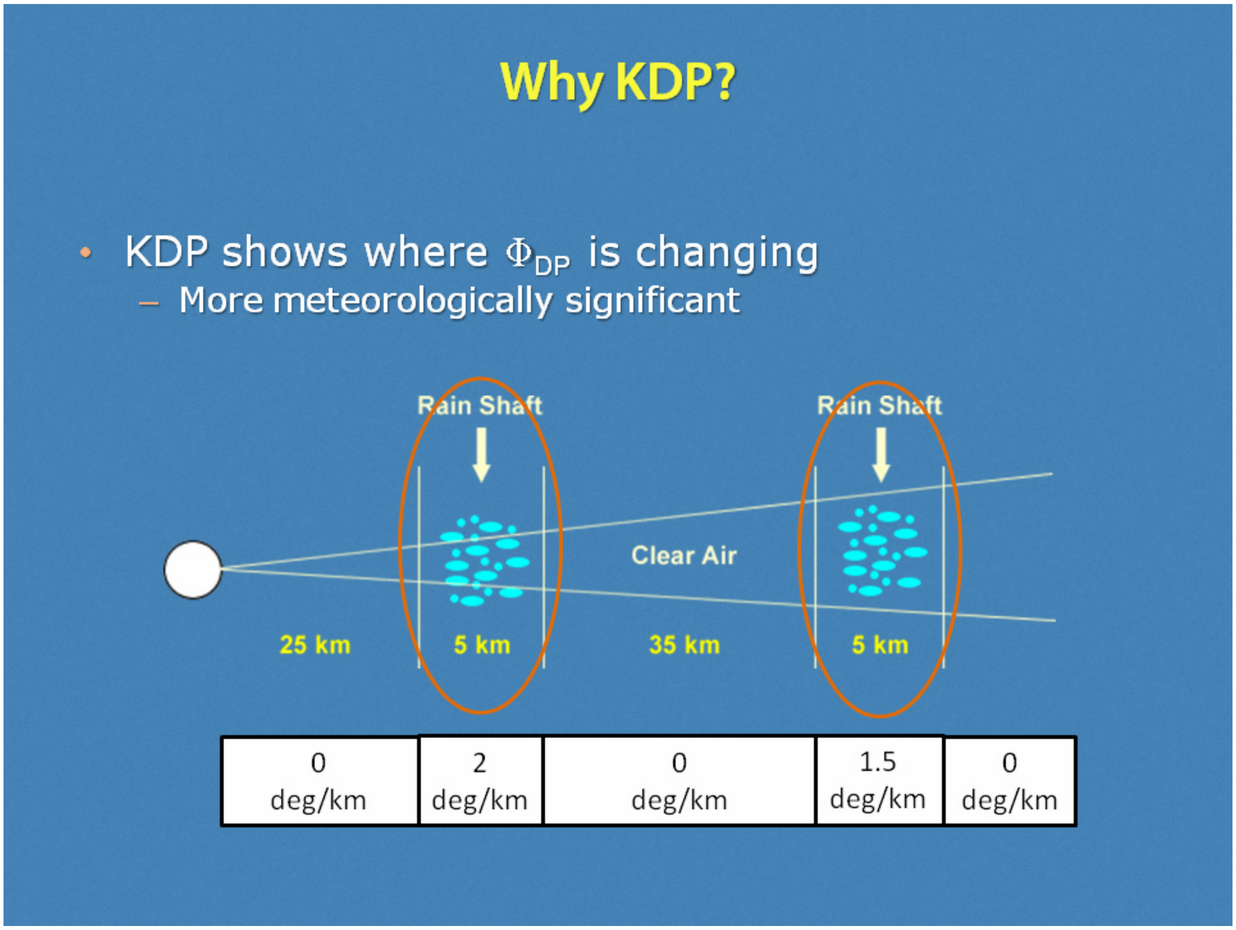
Student Notes:



8. PhiDP in GR Analyst

Instructor Notes: PhiDP is available to view in GR Analyst. Here is an example of what it would look like when there are areas of significant differential phase shift. Notice that it is very difficult to tell where the important areas are because the product is cumulative. In the next slide, we'll see why KDP is more useful operationally.

Student Notes:



9. Why KDP?

Instructor Notes: Now we'll look at the same example except using KDP, or the range derivative of PhiDP. Up until the rain shaft no differential phase shifting is occurring, so 0 degrees divided over any distance will give 0 degrees/distance. Therefore, anywhere within 25 km of the radar has a KDP of 0 deg/km. Inside the rain shaft, we said there was differential phase shifting of 20 degrees. If we divide this by twice the distance over which it occurred (10 km) we get a KDP of 2 deg/km. In the clear air past the first rain shaft, the differential phase shift remains 20 degrees but does not change over this distance. So, KDP will go back to 0 deg/km in this region because the difference between any two differential phase shifts over any distance in this region will be 0. In the second rain shaft, the differential phase shift increases from 20 degrees to 35 degrees, so it increases by 15 degrees. Dividing this value by twice the distance over which it occurred (10 km) gives a KDP of 1.5 deg/km. Past the second rain shaft, the KDP goes back to 0 deg/km for the same reasons it did in the clear air in between the two rain shafts. As you can see, KDP is much better at giving you information about what is happening at that particular bin than is PhiDP.

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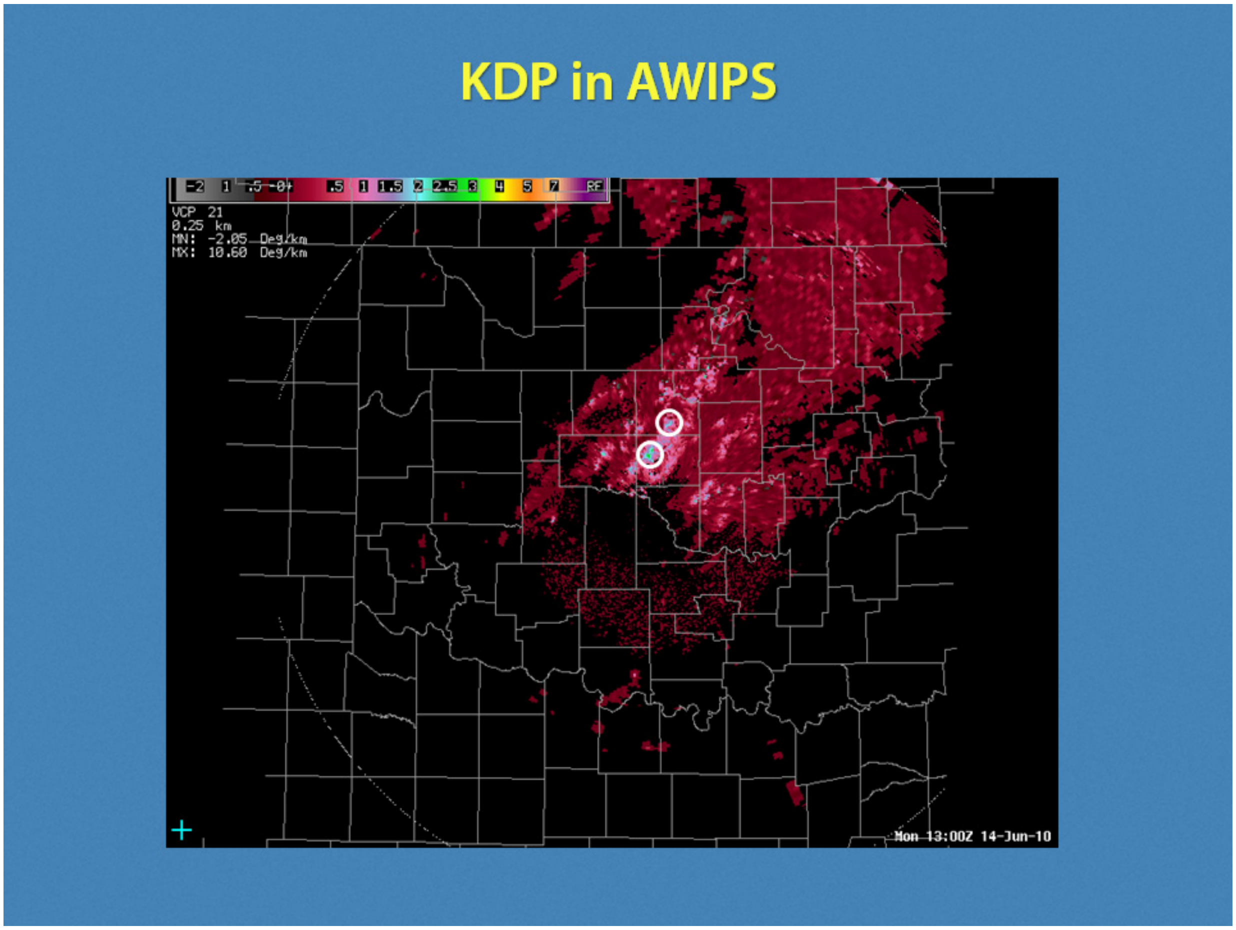
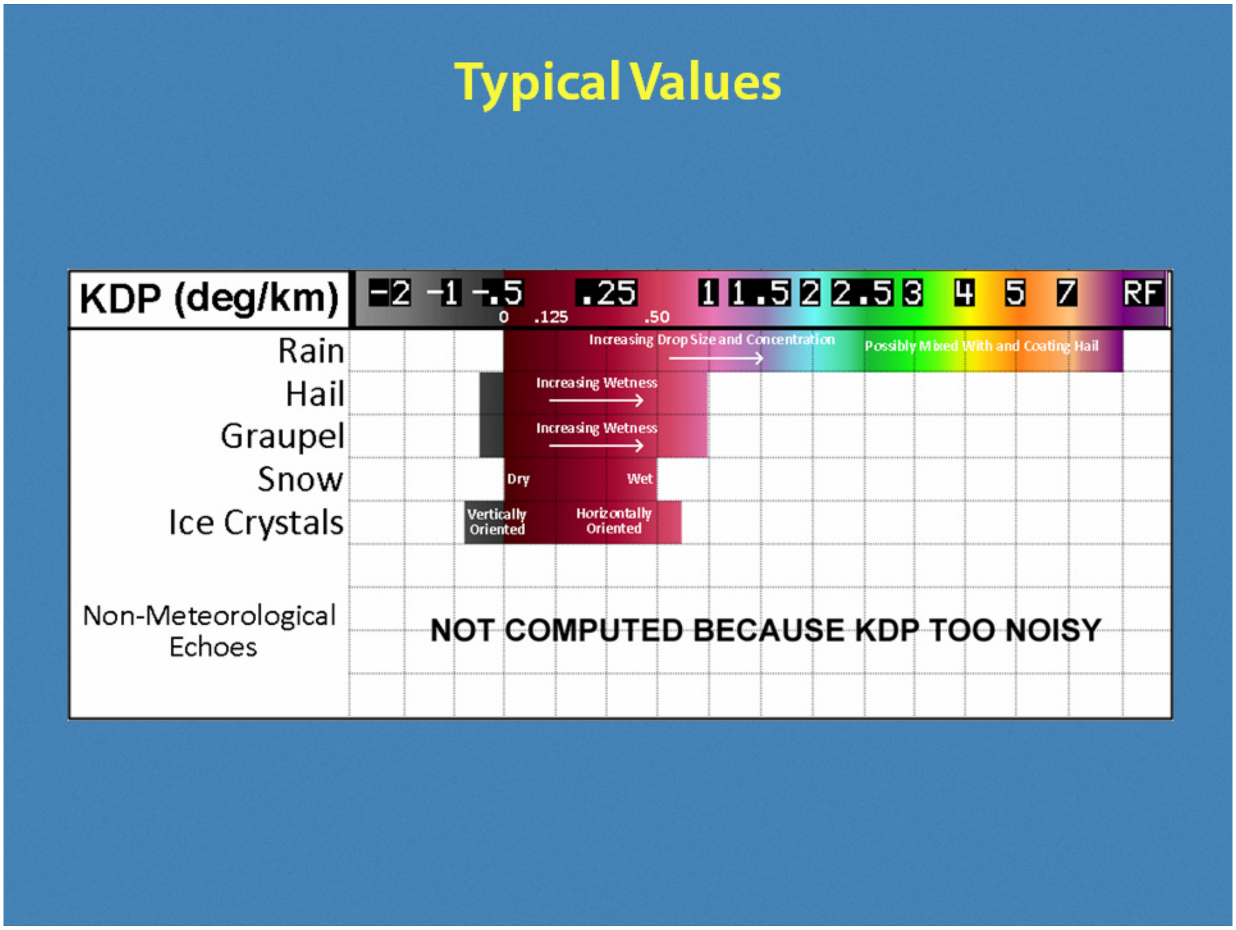


10. KDP in AWIPS

Instructor Notes: Here is the KDP from the example I showed 2 slides ago on PhiDP. Notice how it is much easier to note areas interest.

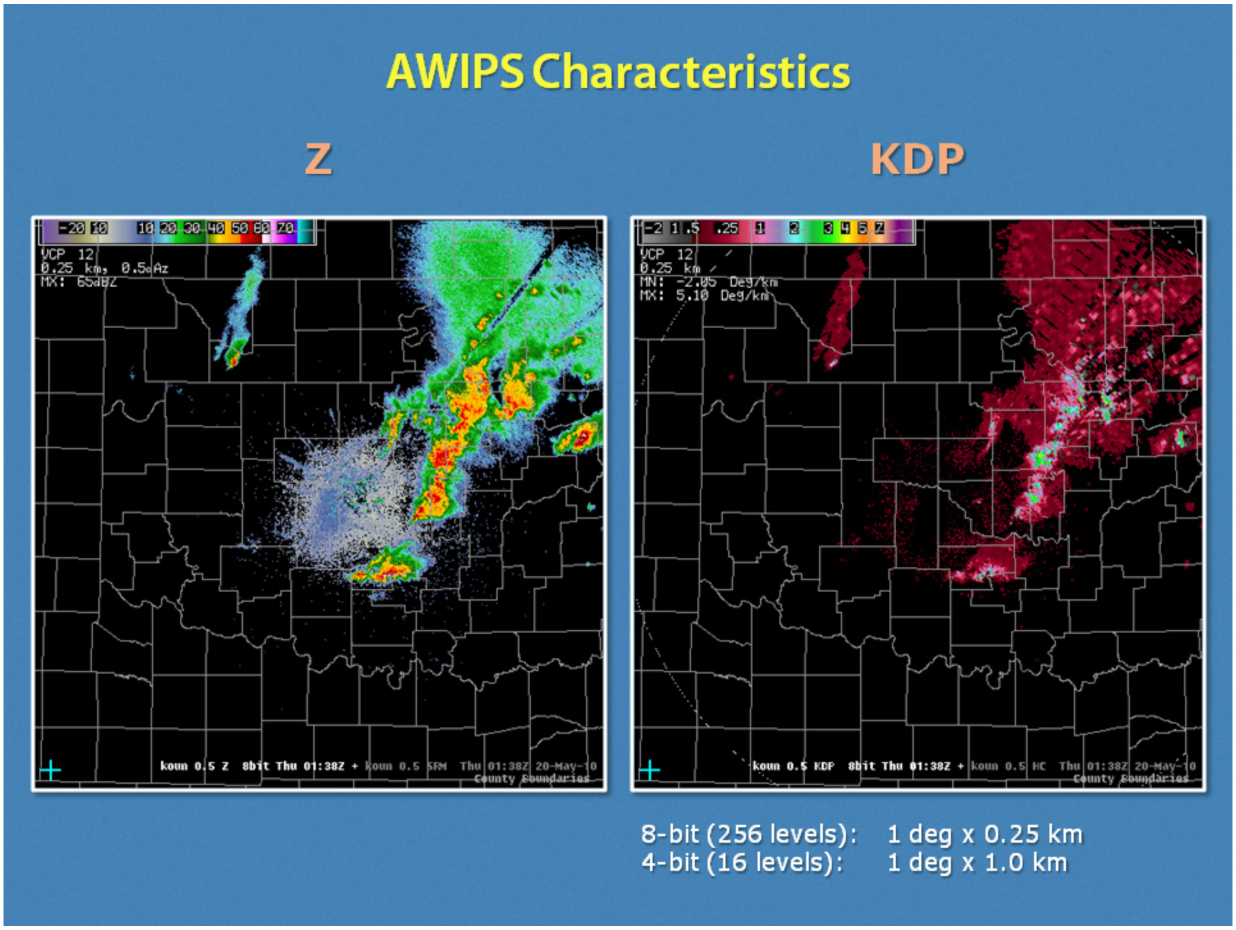
Student Notes:



11. Typical Values

Instructor Notes: Here is a chart of the typical values of KDP for the meteorological echoes listed on the left. Note that non-meteorological echoes do not have typical values listed for KDP. This is because KDP is too noisy for these targets. Please take a few moments to look over this chart.

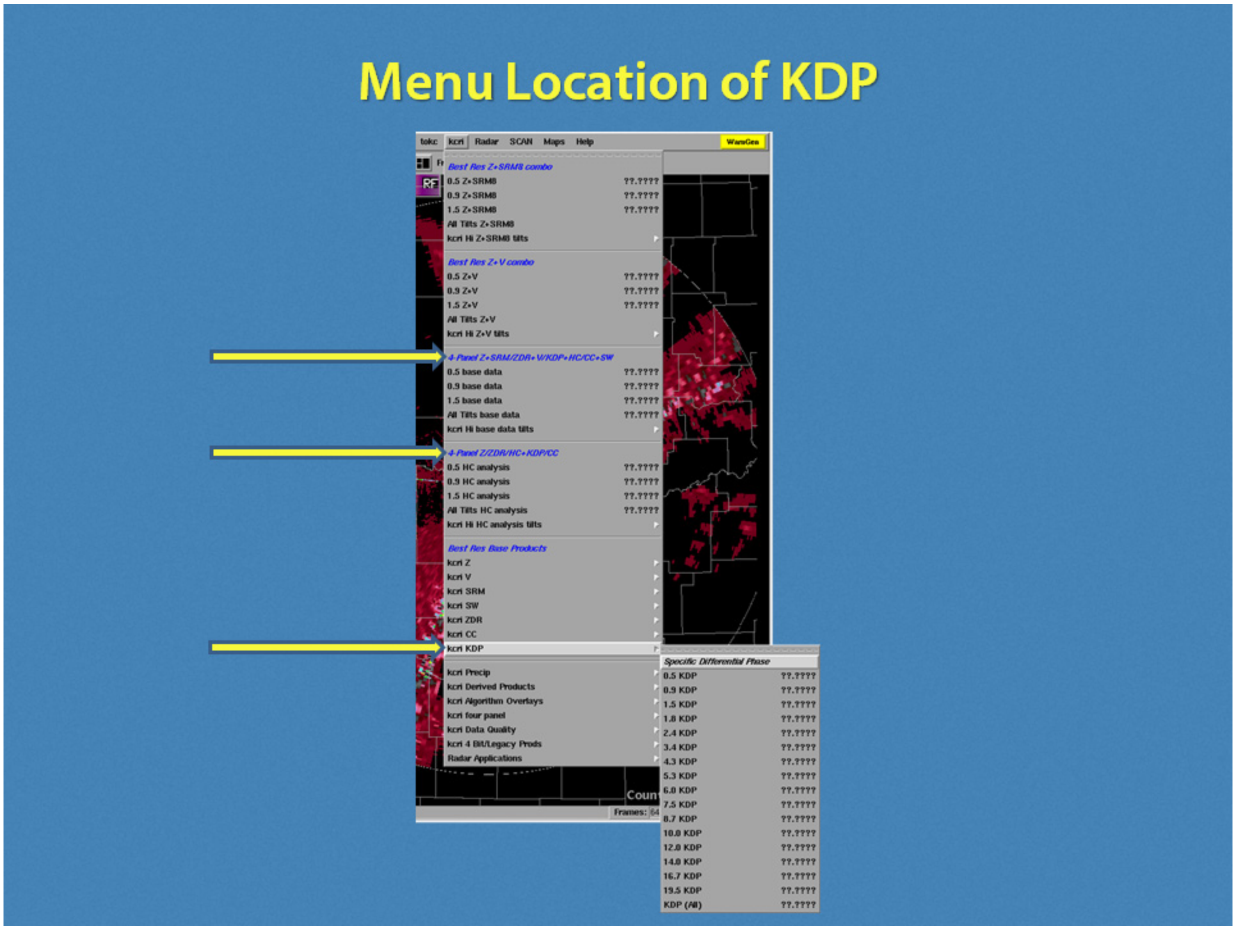
Student Notes:



12. AWIPS Characteristics

Instructor Notes: On the right is an example of what KDP looks like in D-2D with reflectivity shown on the left for reference. KDP will be available in two data levels/resolution: 8-bit at 1 deg x 0.25 km and 4-bit at 1 deg x 1 km. KDP products are available on all elevation angles.

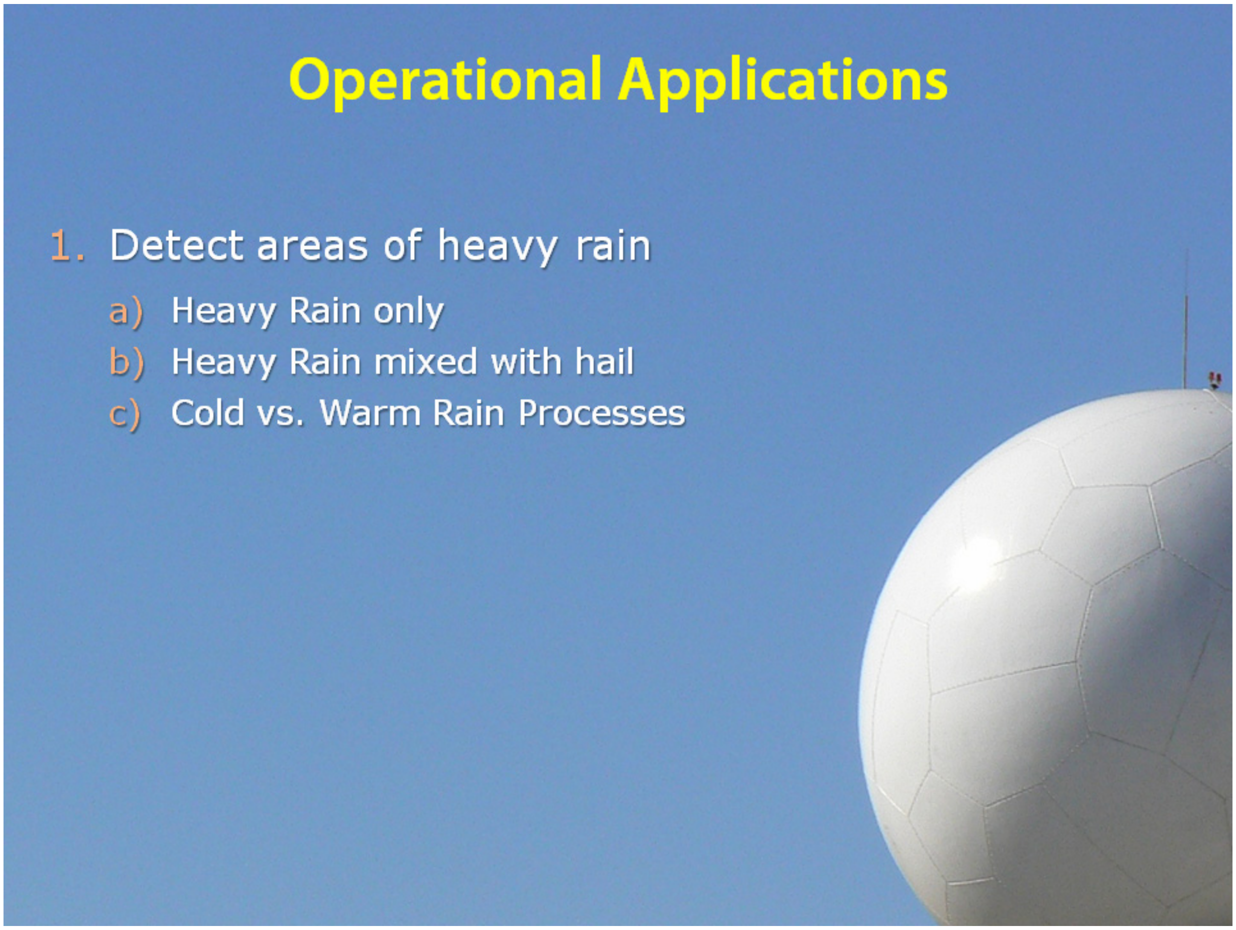
Student Notes:



13. Menu Location of KDP

Instructor Notes: KDP can be found here (yellow arrows) inside your dedicated radar's drop down menu.

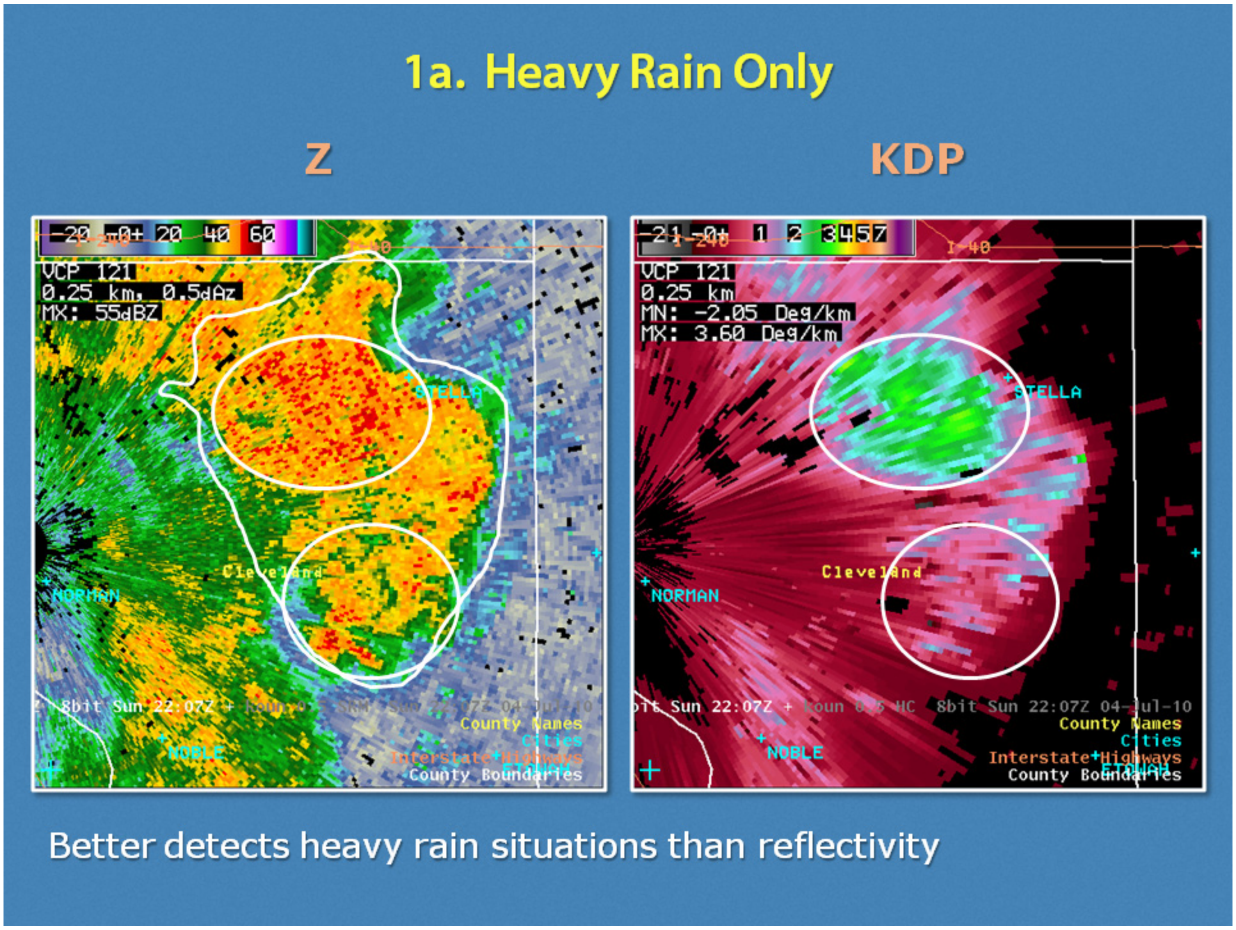
Student Notes:



14. Operational Applications

Instructor Notes: Here is a non-exhaustive list for the operational applications for KDP. We will look at each one of these in more detail over the next few slides.

Student Notes:



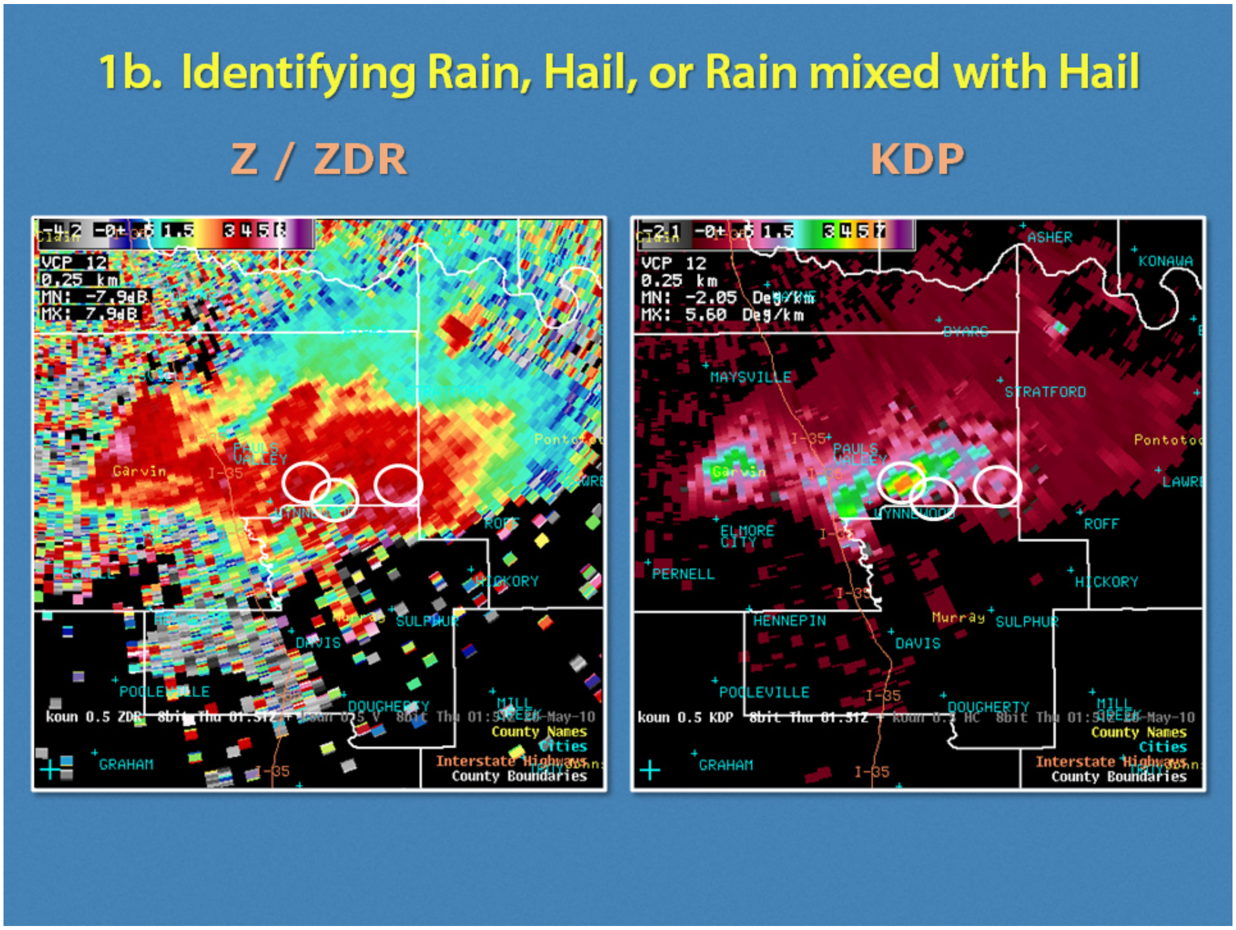
15. 1a. Heavy Rain Only

Instructor Notes: The primary advantage of KDP is its ability to detect heavy rain situations. Here is an example where we have a modest area (big white polygon) of greater than 40 dBZ echoes that is fairly uniform in intensity. Looking at KDP, we see higher KDP values to the north (top white oval), and lower KDP values to the south (bottom white oval) despite reflectivity values being almost identical. This tells us that there is heavy rain falling where the KDP values are higher and not as much rain where KDP is lower.

Student Notes:

16. 1b. Identifying Rain, Hail, or Rain mixed with Hail

Instructor Notes: Another advantage of KDP is the identification of liquid water whether hail is present or not. Let's use this example. Here is a mature supercell that has developed in Southern Oklahoma and has just passed east of I-35. Reflectivity shows a nice forward flank region with an area of greater than 60 dBZ near the inflow region. It also has a well-defined hook echo. Let's focus on three areas. The first area is out toward the edge of the forward flank (far right white circle). Reflectivity (not shown) is near 50 dBZ, and ZDR is around 3 to 4 dB. So we have fairly good-sized, very oblate hydrometeors falling in this region. Looking at KDP, the values are near 1 to 1.5 deg/km. There most likely is not hail in this region and the drops that are falling are most likely large and low in concentration. Moving a bit closer to the core, let's look at this region (middle white circle). Reflectivities (not shown) are once again near 50 dBZ. However, ZDRs in the region are near 0.5 dB and KDP are near 0 deg/km. This tells us that there is mostly hail in this region with little or no liquid water falling to the surface. The last area we'll look at is just to the northwest of where we just looked (far left circle). Reflectivities (not shown) are near 60 dBZ now and ZDRs are back to around 3 to 4 dB. However, now KDP is on the order of 5 deg/km. This tells us a couple possible things. One, there is melting hail (given the 60 dBZ) or that there is a substantial amount of liquid water falling with the possible hail in this region. Either way, there is substantial liquid water in this region as compared with the other two.



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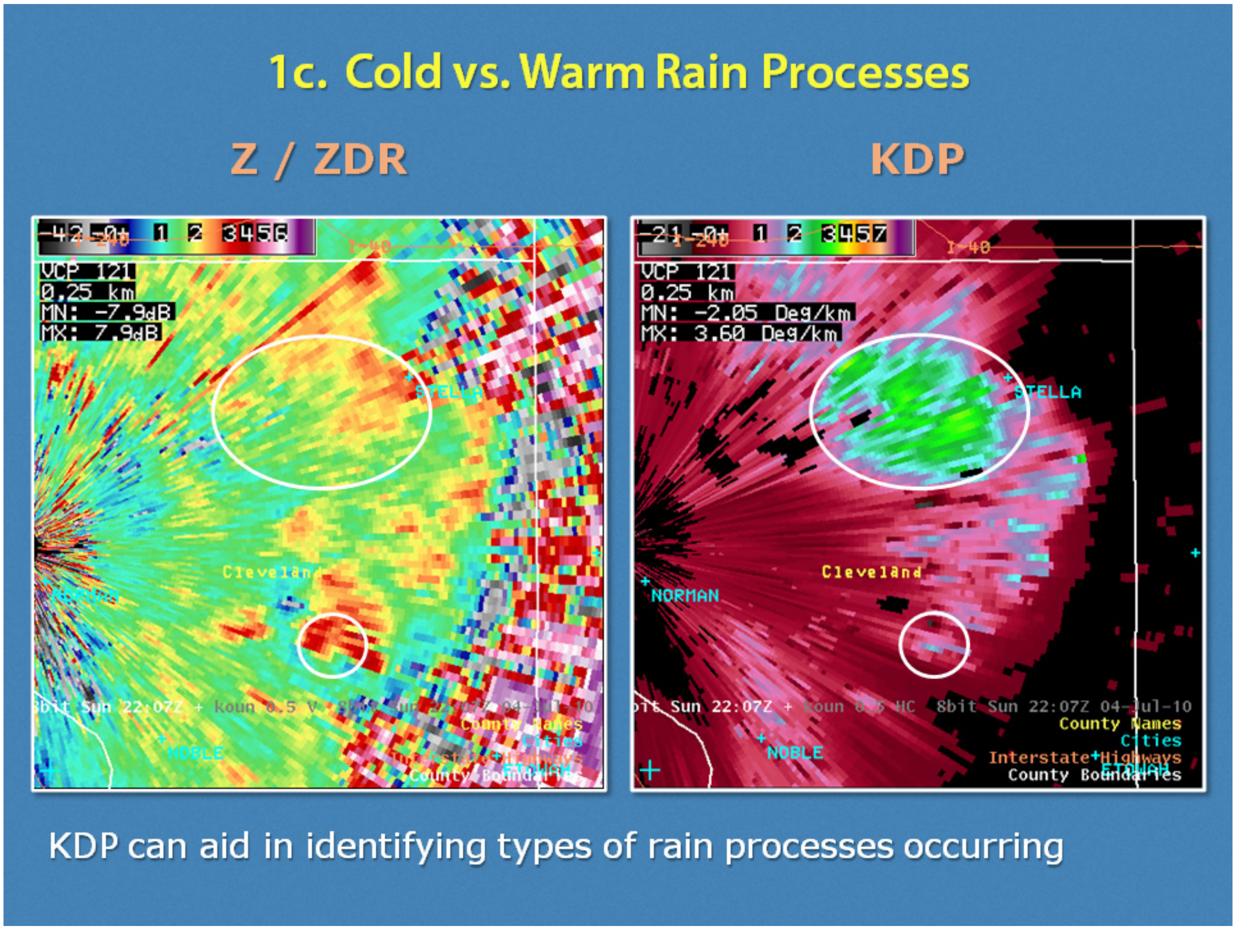
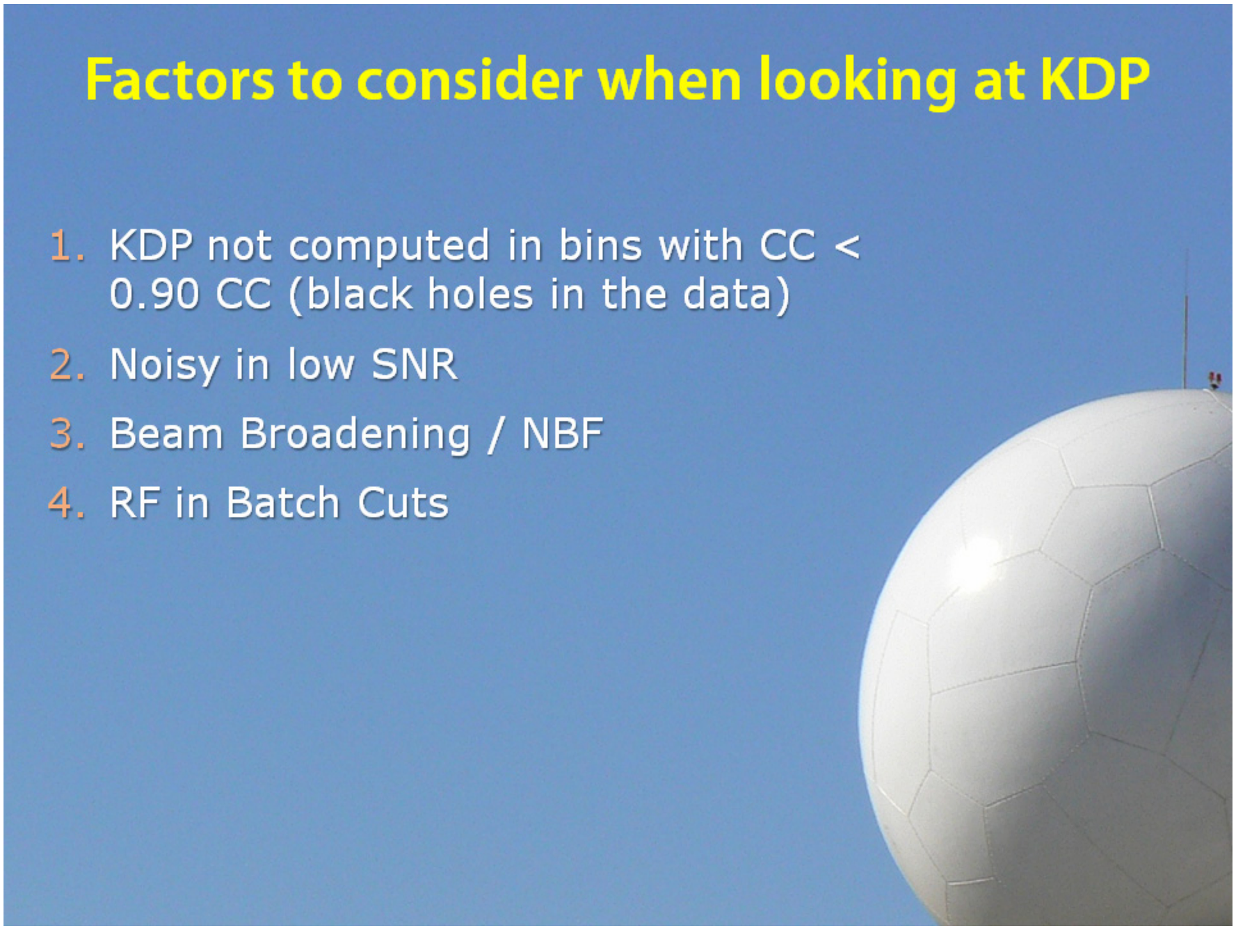


17. 1c. Cold vs. Warm Rain Processes

Instructor Notes: Let's take a deeper look at the example from a couple slides ago. Remember that I mentioned there was heavy rain occurring to the north and not as much rain occurring to the south based on the KDP values despite there being similar reflectivity values. The two areas we will take a look at here are defined by these white circles. If we look at ZDR, the northern area has ZDR values around 1.5 to 2.5 dB. Down south, the ZDR values are approaching 3 dB. Remember from the ZDR lesson, this tells us the drops to the south are larger in size than the drops to the north. However, if we look at KDP, the higher values are to the north. How does this make sense? How can smaller drops be producing a higher rain rate than larger drops? The answer is in the concentration of the two types of drops. Remember, KDP is dependent not only on the shape of the particle, but its concentration. So, if the rain to the north is smaller in size but has higher KDP, it has to be because the concentration of the drops to the north is higher than the drops to the south. The reason for that is the type of process by which the drops formed. The drops to the north most likely formed via a warm rain process whereas the drops to the south formed via a cold rain process.

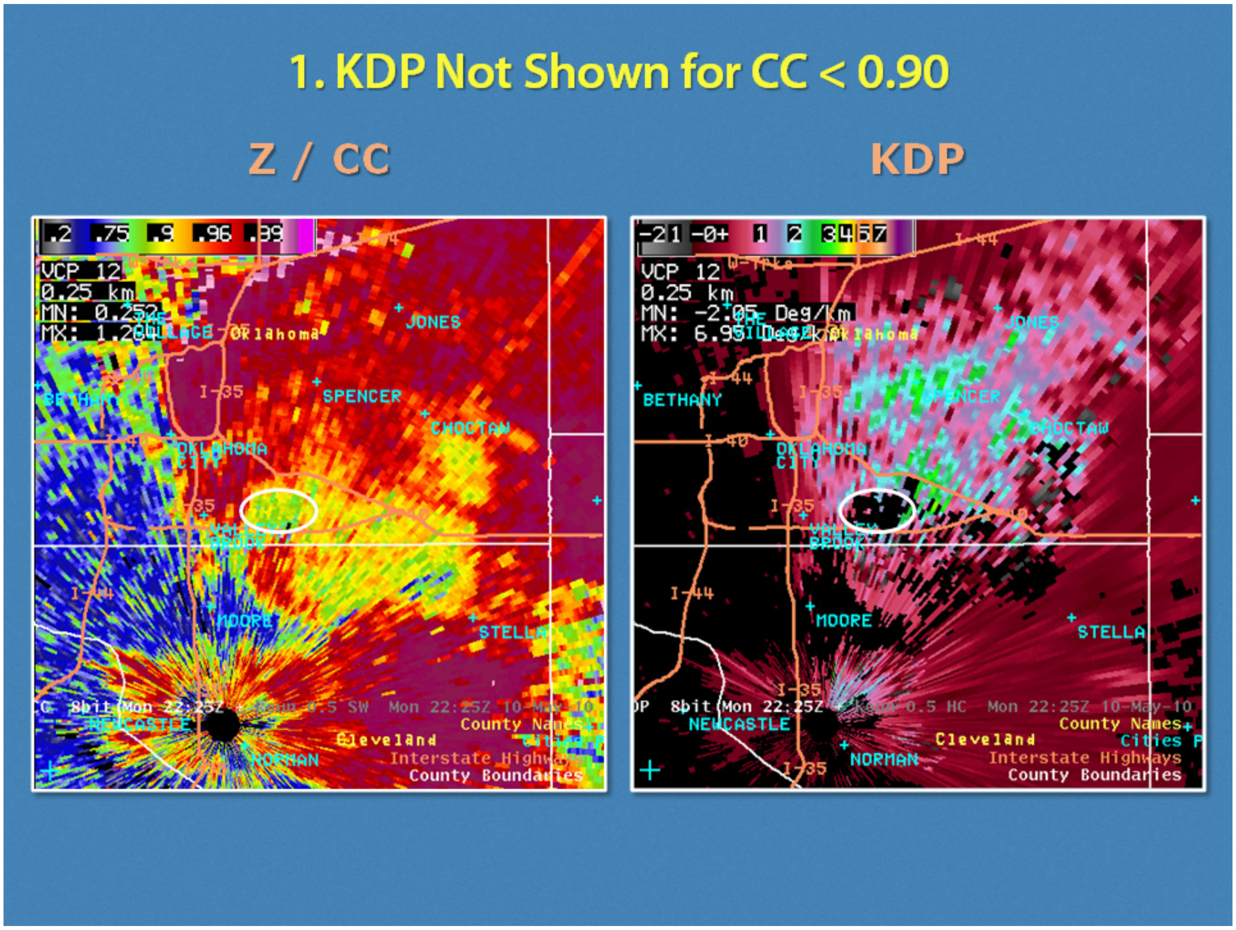
Student Notes:



18. Factors to consider when looking at KDP

Instructor Notes: Here is a non-exhaustive list for the limitations for KDP. We will look at each one of these in more detail over the next few slides.

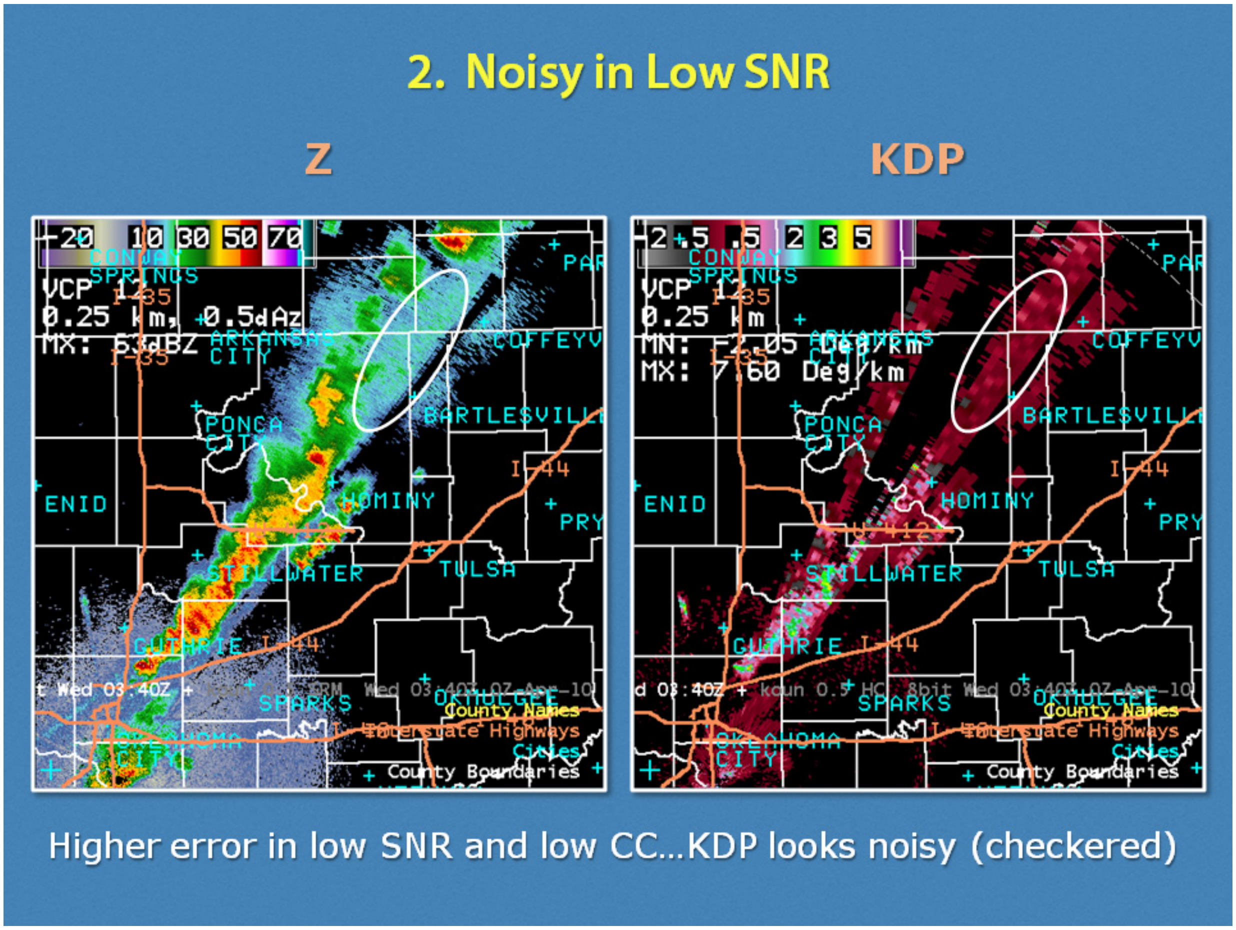
Student Notes:



19. 1. KDP Not Shown for CC < 0.90

Instructor Notes: When the CC is below 0.9, KDP becomes too noisy and is not computed at the RPG. Therefore, in bins with CC less than 0.9, KDP will not be plotted, so it will appear as black holes in the data. Here is an example from 2225 UTC on 10 May 2010 of a supercell that moved through central Oklahoma. It produced up to softball-sized hail and an EF-4 tornado. Looking in the hail core (white circle) where the softball hail was falling, we see CC below 0.9. Toggling over to KDP, we see that in this region, KDP is not computed and appears as a black hole in the data.

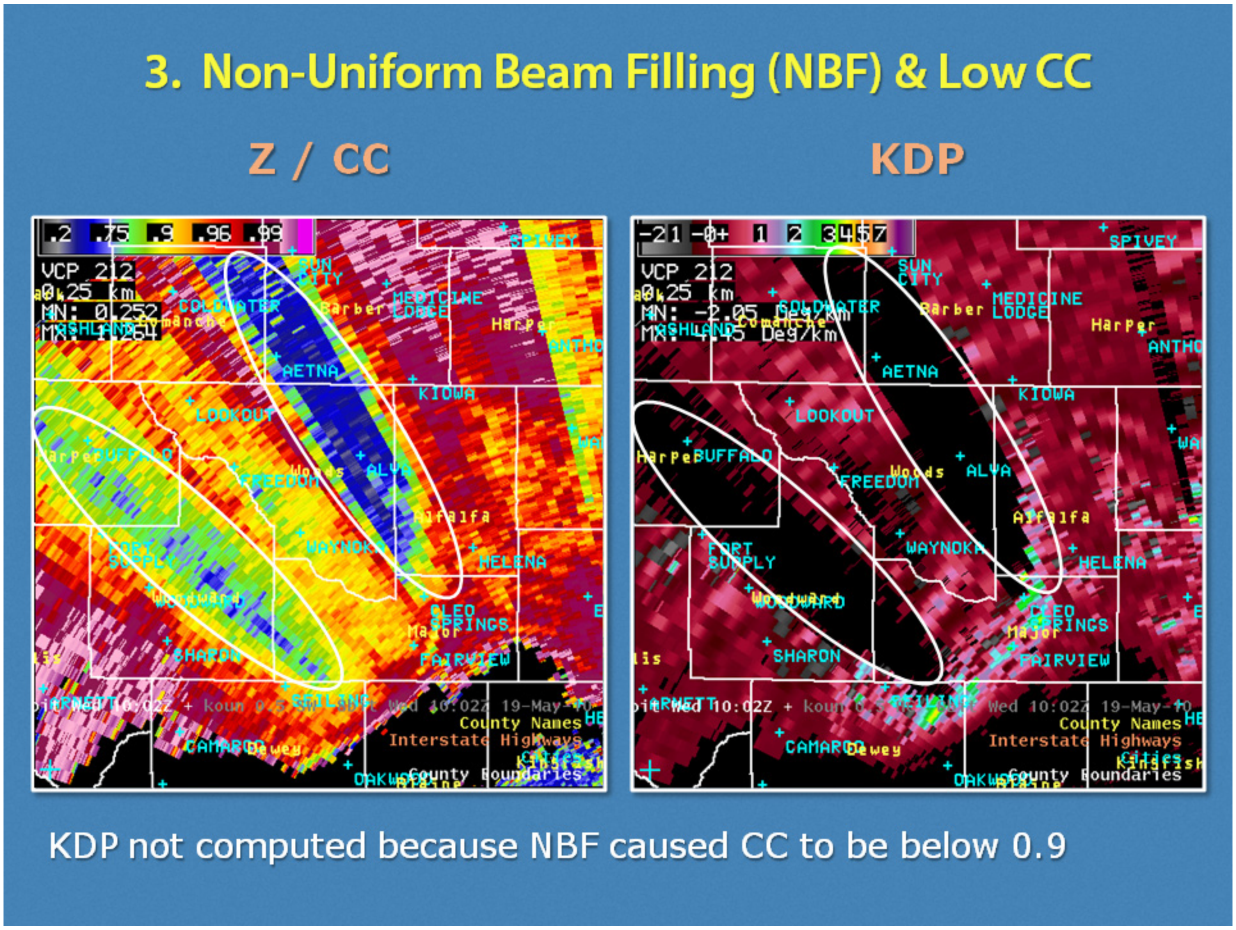
Student Notes:



20. 2. Noisy in Low SNR

Instructor Notes: Here we will examine the effects of low SNR on the error in estimation of KDP. In areas of low SNR, KDP will become noisy. In this example, the echoes highlighted are at far range from the radar and have low returns (< 25 dBZ). Therefore, the SNR is very low. Looking at KDP, we see that it looks very speckled (or noisy). Common situations where SNR is low is low reflectivity at far ranges and weak reflectivity along the very edges of storms. You may have also noticed the huge area of black (no data) along radials to the NW of the oval. This is a by-product of the first limitation, where KDP is not computed with bins that have CC < 0.90.

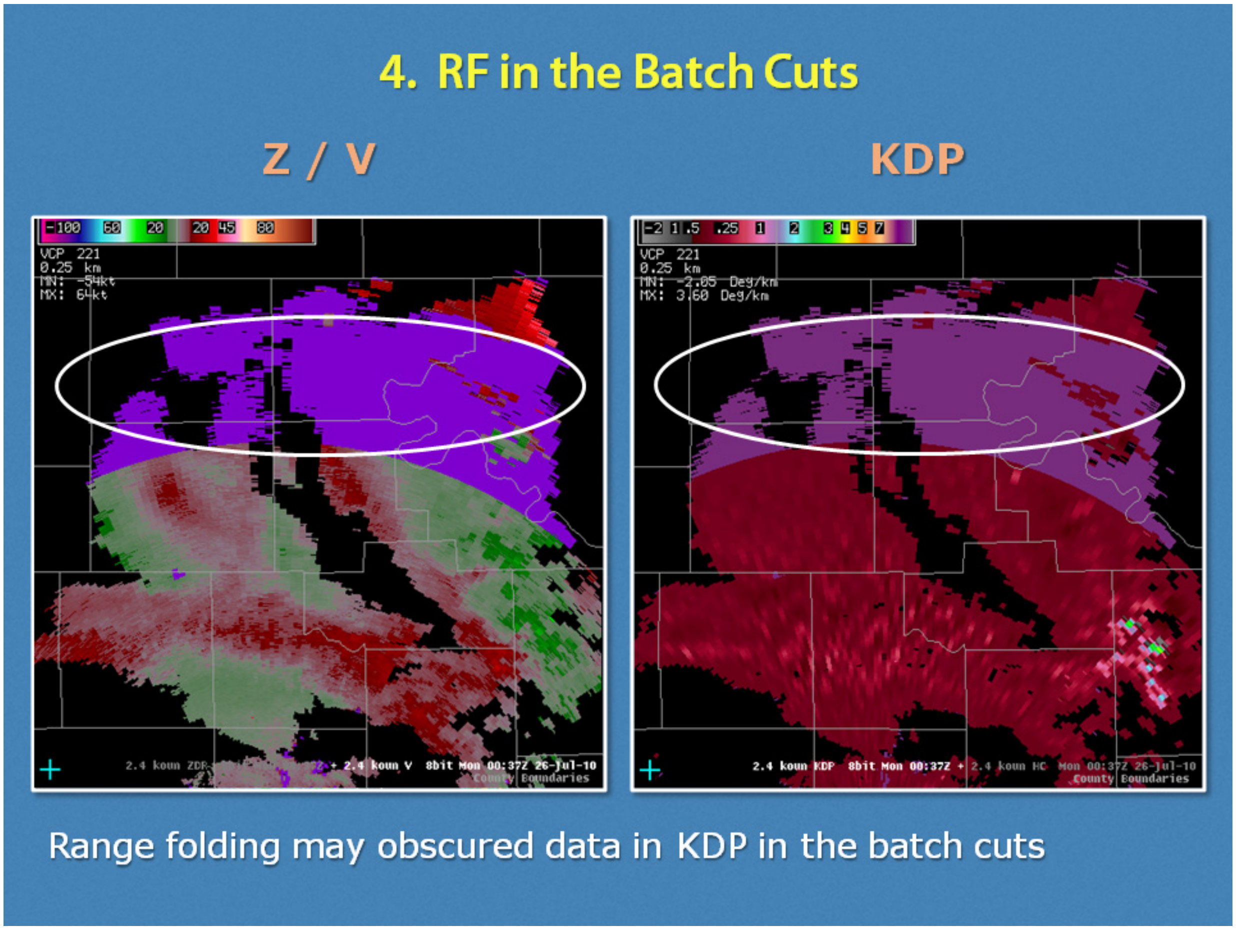
Student Notes:



21. 3. Non-Uniform Beam Filling (NBF) & Low CC

Instructor Notes: As was mentioned with CC, we examined the causes of non-uniform beam filling and how it affected CC. Remember, non-uniform beam filling occurs when significant gradients of differential phase occur within a pulse volume. This gradient can either be in the horizontal or vertical. The same applies for KDP primarily because if CC becomes affected by NBF and drops below 0.9, KDP becomes unreliable, and is not computed. Therefore, KDP will be unreliable in areas where lines of storms align along a radial, near the melting layer, and at long ranges. Here is an example of where NBF has caused KDP to not be computed because CC dropped below 0.9 due to NBF.

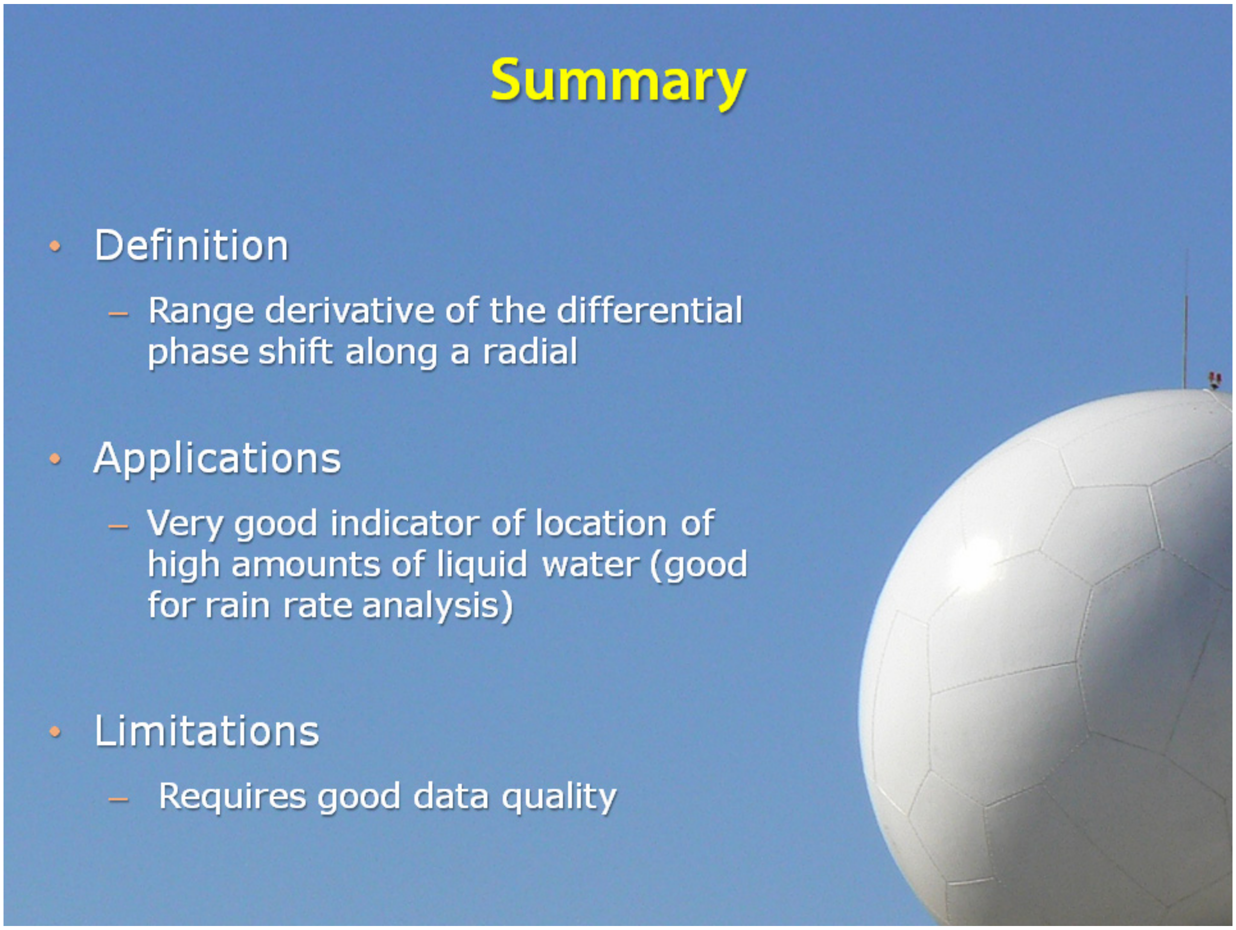
Student Notes:



22. 4. RF in the Batch Cuts

Instructor Notes: As with ZDR and CC, KDP will also have RF in the batch cut elevations. Here is an example from 26 July 2010 at 0037 UTC from the 2.4 degree elevation scan where you can see RF in the velocity. Switching over to KDP, you can see that where there is RF in velocity, there is RF in KDP.

Student Notes:



23. Summary

Instructor Notes: In summary, we have learned that the specific differential phase is the range derivative of the differential phase shift along a radial. Operationally, it is a great product to use for rain rate analysis, however it requires good data quality to be useful.

Student Notes:

24. Conclusion

Instructor Notes: This concludes the lesson on KDP, and thanks for your attention. If you have any questions, you can send an email to the dual polarization operations course help list (dualpol_list@wdtb.noaa.gov).

Student Notes: